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Assessments of Atlantic salmon stocks in southwest New Brunswick, 1999

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Abstract

Assessed stocks of Atlantic salmon in southwest New Brunswick did not meet conservation requirements in 1999 and probabilities of achieving requirements in 2000 are virtually zero. Egg depositions for the Saint John River stock upriver of Mactaquac rose to 31% of the conservation requirement, and wild salmon continued to be at record lows. The Nashwaak River stock achieved only 19% of its requirement. Stocks of the Kennebecasis and Hammond rivers are unlikely to have met conservation requirements. Stocks of outer Bay of Fundy rivers west of the Saint John River system (e.g., Magaguadavic River) have declined markedly in the last decade and action is required to prevent their extirpation.

In spite of long-standing restrictive fisheries management measures on salmon in distant and home-water areas, returns have fallen short of conservation requirements and expectations. These low returns have been associated with low marine survival. Other constraints include hydroelectric dams (mostly devoid of safe downstream passage), artificial flow regimes, headponds, predators, and potential transmission of diseases and genetic swamping from nearby aquaculture facilities.

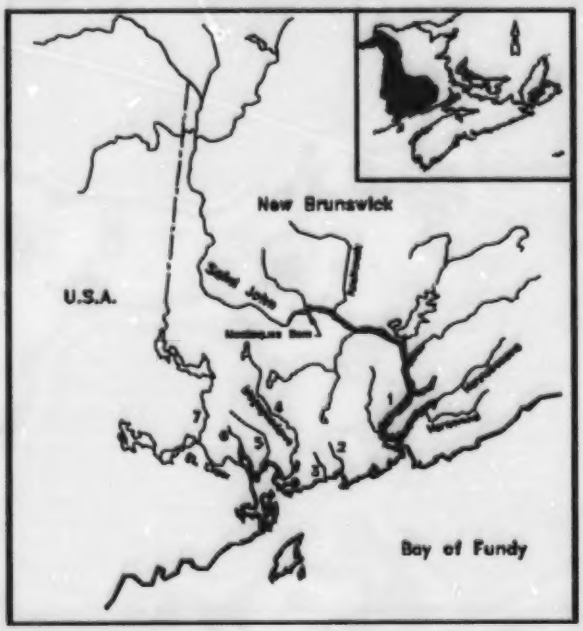
Résumé

Les besoins de conservation n'ont pas été atteints dans les stocks évalués de saumon atlantique du sud-ouest du Nouveau-Brunswick en 1999, et les probabilités qu'ils le soient en 2000 sont quasiment nulles. La ponte du stock de la rivière Saint-Jean en amont de Mactaquac correspondait à 31% des besoins de conservation, et le saumon sauvage se maintient à un seuil sans précédent. Le stock de la rivière Nashwaak n'a atteint que 19% de ses besoins. Il est peu probable que les besoins de conservation aient été comblés pour les stocks des rivières Kennebecasis et Hammond. Les stocks des rivières de l'avant-baie de Fundy à l'ouest du bassin hydrographique de la rivière Saint-Jean (p. ex. la rivière Magaguadavic) ont considérablement chuté durant les dix dernières années, et des mesures sont nécessaires pour empêcher leur disparition.

Malgré les mesures de gestion restrictives appliquées depuis longtemps à la pêche du saumon dans les eaux d'origine et dans les eaux lointaines, les remontes n'ont pas satisfait aux besoins de conservation et aux attentes. Cette diminution des remontes a été associée à une réduction de la survie en mer. D'autres obstacles sont les barrages hydroélectriques (généralement dépourvus de moyens de passage sécuritaires vers l'aval), les régimes d'écoulement artificiels, les retenues d'amont, les prédateurs, ainsi que les risques de transmission de maladies et d'invasion génétique provenant des installations d'aquaculture à proximité.

Introduction

Stocks in southwest New Brunswick have generally not been meeting conservation requirements during the last decade and have been closed to recreational retention fisheries for 1SW salmon (grilse) since September 15, 1993. Aboriginal food fisheries (main Saint John River and Tobique River tributary) and hook-and-release fisheries for grilse (various season lengths) were permitted in 1994, 1996 and 1997 but virtually closed in 1995 and closed in 1998 and 1999. In-season assessments at Mactaquac have been used as an index of stock status throughout southwest New Brunswick.



Saint John, Upriver of Mactaquac

Fishery

In 1999 the fishery for salmon on the entire Saint John River was again closed to both Aboriginal and recreational anglers. This did not, however, deter some few members of Maliseet First Nation from a fishery, which by DFO estimates, yielded an estimated 230 salmon (Table 1). The 1999 closure followed that of 1998 and a pre-season forecast for 1999 that conservation requirements were again highly unlikely to be met. An assessment at Mactaquac on July 15, 1999, when about one-quarter of 1SW fish and one-half MSW fish would normally have been counted, 1989-1998, indicated a near-zero probability that conservation egg requirements would be met.

Status

Habitat

Salmon returning to Mactaquac Dam and Hydroelectric Station are trapped at the Mactaquac collection facilities, transported to the sorting facilities, sampled and trucked upriver of Mactaquac dam. Fish are taken to either the Woodstock release site on the mainstem upriver of Mactaquac or upriver of the Beechwood and Tobique Narrows dams to the Arthurette release site on the Tobique River. A few salmon are transported upriver of the Beechwood and Tinker dams to the Aroostook River release site. About 150-170 of each of male and female salmon are held at Mactaquac for spawning and production of approximately 1.2 million juveniles to mitigate the impact of hydroelectric development. Upstream fish passage facilities are provided at each of the Beechwood, Tobique and Tinker dams. None of these dams have downstream passage facilities and thus adults (those misplaced by trucking and kelts) and smolts must descend through spill gates during spate conditions or through turbines during generation of power.

Four adult mortalities found on the main stem proximite to the Mactaquac facilities were submitted to the federal fisheries health lab for disease analyses. Analyses includes testing on an individual basis for all the Fish Health Protection Regulations 11 "identifiable diseases": IHNV, IPNV, ISAV, OMV, VHSV, BKD, ERM, Furunculosis and Whirling Disease as well as rt-PCR for ISA virus on serum. One of the fish, a mortality taken below the trap in the migration channel, was diagnosed to have *Aeromonas salmonicida*, the causative agent of furunculosis, which is ubiquitous to the Saint John drainage. The first 17 of 20 sorted fish suspected of being of aquaculture origin have tested completely negative, results for the remainder are pending. An additional 30 broodstock have tested negative to date, rt-PCR on serum for ISA virus, being as yet incomplete.

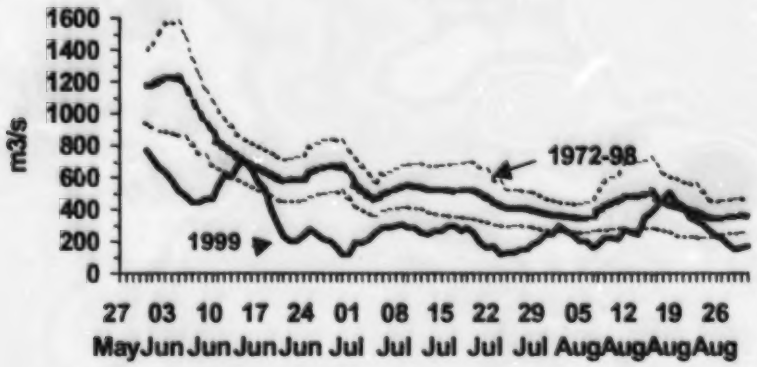
Juvenile salmon production area on the mainstem Tobique (largest salmon producing tributary above Mactaquac) is subject to highly variable flows released from three storage reservoirs to meet peak power generation at the Tobique Narrows hydroelectric station. Peak power generation by the five major stations (including Grand Falls on the mainstem which is a complete barrier to salmon migration) contributes to a highly erratic, especially during annual spring floods, and largely disrupted mainstem environment.

Since construction, the Mactaquac, Tobique and Beechwood headponds have become home to mature communities of non-indigenous smallmouth bass, *Micropterus dolomieui*. More recently, muskellunge, *Esox masquinongy* have been increasing in numbers in the mainstem downriver of Mactaquac and in Glazier Lake (New Brunswick-Maine boundary waters) upriver of Grand Falls (Stocek *et al.* 1999). Chain pickerel, *Esox niger* may also be expanding into more lacustrine environments. These species are potential predators of overwintering presmolts and spring migrating smolts. Downstream migrating smolts from the Tobique River descend through three headponds and dams. In general about half as many smolts from the Tobique return as adults as compared to adult returns from smolts released downstream from Mactaquac dam. Non-indigenous

populations of brown trout, *Salmo trutta*, persist in the Meduxnekeag and Presquile rivers.

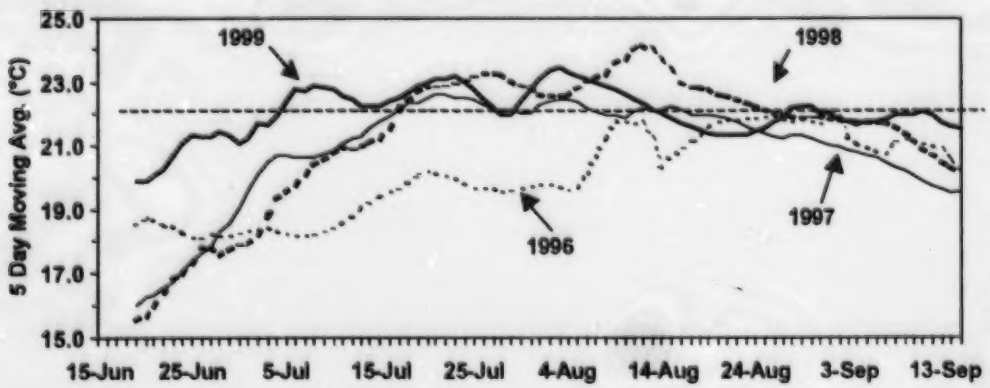
Water quality, with the exception of high turbidity caused by ice scouring during the annual spring floods, is generally improved over the last four decades. This is a result of new and improved industrial and community sewage treatment facilities both above and below Mactaquac. River discharges at Mactaquac Dam, June through August, were among the lowest of record and, for the most part, outside the 95% confidence intervals of the mean of the previous 27 years. September and particularly October rains returned discharges to more normal levels.

Discharge at Mactaquac
1999 and mean 1972-98±95%CL



Days on which water temperatures equaled or exceeded 22°C at Mactaquac fishway in 1999 numbered 42 days. Those of 1998 numbered 41, while those of 1997 and 1996 numbered 36 and 22 days respectively. The most notable difference between years was the early onset of the warmer waters.

Maximum Water Temperature - Mactaquac Fishway



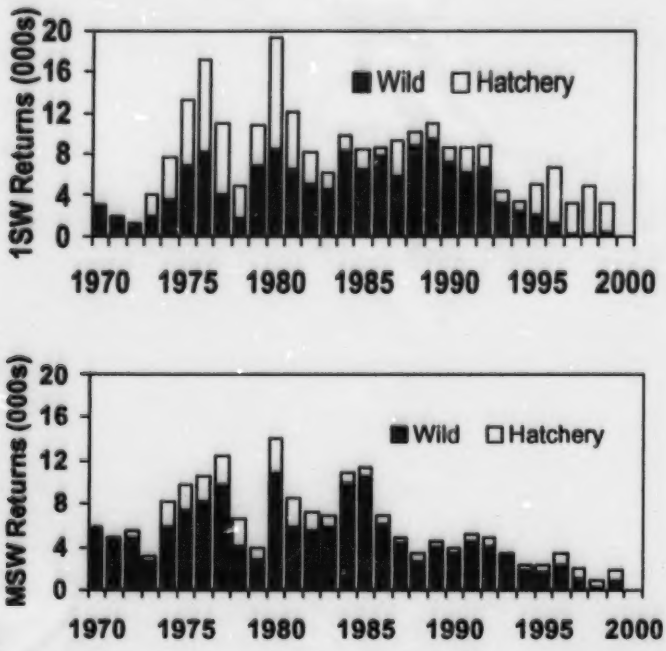
Stock

Returns to Mactaquac in 1999 are the sum of salmon captured at the dam and in the hatchery migration channel, and assumed to have been lost (1% of 1SW and 2.5% of MSW returns to the river) to bycatch in the downriver shad and gaspereau fishery or poached in the area between Fredericton and Mactaquac. While the total count of fish is fixed, the proportions of hatchery and wild 1SW and MSW salmon are dependent on an interpretation of ages from scale samples.

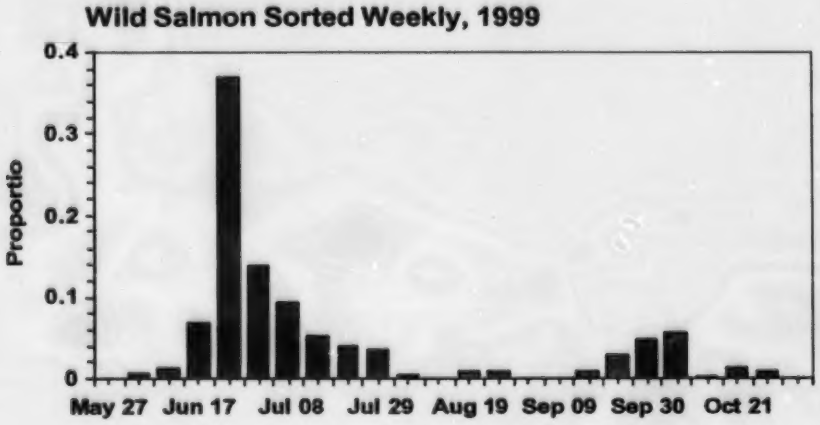
The total count at Mactaquac in 1999 was 5,003 fish and based on size was comprised of 3,211 1SW and 1,792 MSW salmon. Twenty fish had fin deformities and body shape consistent with escaped farm salmon. The examination of growth characteristics on scales i.e., freshwater- and sea-age (Marshall *et al.* MS 1997); separation on the basis of scale pattern analyses [Stokesbury *et al.* MS 1999] (requires further exploration) suggested total returns (including assumed losses downriver of Mactaquac) of 3,257 1SW and 1,804 MSW salmon (Table 2). Exclusive of aquaculture fish, 472 1SW fish (14% of total) were estimated to be of wild origin. Of the MSW fish, 837 (46%) were of wild origin.

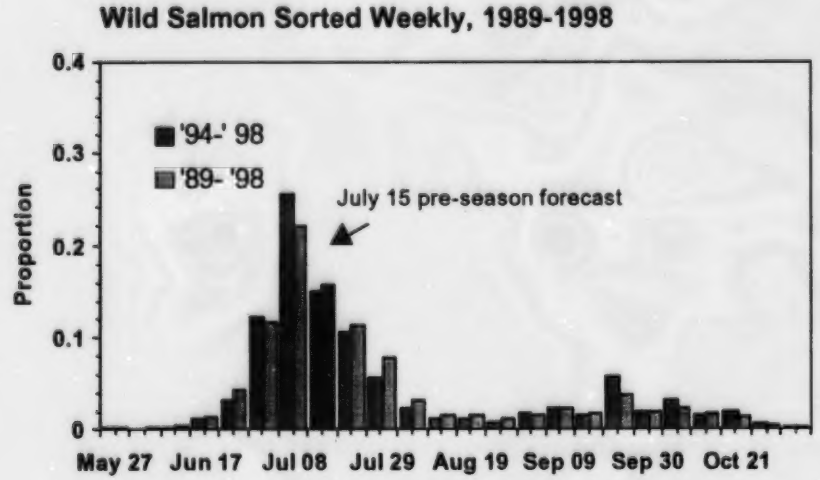
Estimates of wild 1SW returns exceed returns in 1998 (by 131 fish), and are the third lowest of a 30-year record; wild MSW returns are 2.5 times those of 1998 but are the second lowest of the 30-year record. Hatchery 1SW returns are fewer than values estimated since 1994. Hatchery MSW returns were 149% of those in 1998, about the same as those of 1997, and with one exception exceeded estimated returns since 1984.

Returns to Mactaquac



Run-timing of wild and hatchery 1SW and MSW salmon to Mactaquac in 1999 was significantly earlier than observed over the period 1972-1998. The anomaly was fairly evident prior to in-season forecasts of the end-of-season counts conducted on July 15. At that time, evidence was presented to suggest that returns appeared to be two weeks early and that the appropriate forecast models for July 15 would be those normally used on July 29. Season-end plots of the weekly proportion of wild MSW counts at Mactaquac in 1999 and the previous ten-year average appear below.





The magnitude of difference in the proportions of the total season count tallied by July 1 in 1999, relative to the average of the previous ten years, was large for each of wild and hatchery 1SW fish as well as wild and hatchery MSW salmon.

Category of salmon	1999	1989-1998
Wild MSW	0.59	0.17
Hatchery MSW	0.64	0.09
Wild 1SW	0.31	0.03
Hatchery 1SW	0.40	0.01

The distribution of weekly counts in 1991, when river discharges at Mactaquac in late June were the lowest of record, were, on inspection, not different from those of the 1989-1998 average.

To investigate the efficiency of an upgraded fishway at Tobique Narrows (and address the outstanding issue of "free swim"), 269 1SW and 292 MSW wild fish were tagged at Mactaquac prior to release 75 km "upriver" of Mactaquac at Woodstock in 1999. A side-light of the investigation was the evidence that some fish of Nashwaak origin continue to be captured at Mactaquac and trucked upriver and that a significant proportion of the few tagged 1SW fish smolt age one (Mactaquac origin tagged mistakenly as "wild" fish) returned from Woodstock to either the dam or migration channel at the Mactaquac Hatchery. At least 14 fish of Nashwaak origin were estimated to have been transported upriver from Mactaquac (see Nashwaak River). Thirteen of 32 (41%) mistakenly tagged smolt age one hatchery fish trucked to Woodstock returned to Mactaquac, which suggests that of another 741 untagged fish, 300 from Woodstock may have returned to Mactaquac and been double counted. Fallback of smolt-age 1 1SW hatchery fish released at the Arthurette dumpsite on the Tobique River could not be addressed. Three other 1SW fish (two of unknown smolt age and one of smolt age two) and one wild salmon also returned to Mactaquac. Results indicate a requirement to assess, through more focused tagging of hatchery returns, the possible inflation of counts and returns to Mactaquac because of double counting, factors which may influence the rate of fallback and disposition of hatchery origin fish to maximize benefits from egg depositions.

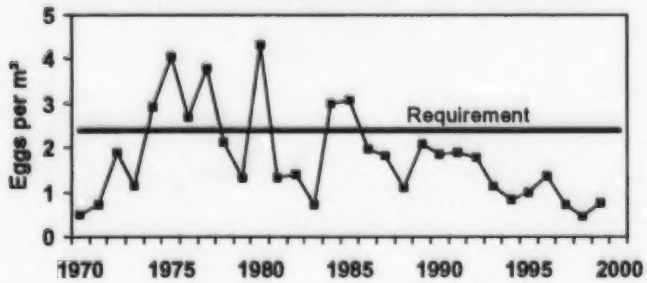
The fallback issue was last examined in 1972-1973 (Marshall MS 1975). Both hatchery and wild fish were tagged and released at a former dumpsite immediately above Mactaquac Dam, at Woodstock and at Tobique dumpsites. The Woodstock dumpsite has remained in approximately the same location, about 17 km below the upstream limits of the headpond at Hartland, but since 1979-1981, has an additional one-two m of depth. Results from 1973 indicated that only one of 28 (3.6%) hatchery-origin MSW salmon and one of 125 (0.8%) hatchery 1SW fish released at Woodstock were recovered downriver of Woodstock. More than one-half of the releases appear to have been in September and October. Other notes of interest from all releases and release sites include: 1) upstream movement seemed to be related to river discharge; 2) there was a four-fold variability between fallbacks of hatchery salmon from the Mactaquac dumpsite between 1972 and 1973; 3) the rate of fallback decreases after early September; 4) just-tagged fish move upriver at one-half the rate of previously-tagged fish; and 5) four of approximately 700 experimental wild fish were recovered in the Nashwaak River.

Escapements are those fish returning to the dam minus, among others, 315 MSW and 25 1SW fish retained at Mactaquac as broodstock, 64 1SW and 10 MSW fish transported above Tinker dam on the Aroostook River, 8 1SW and 6 MSW mortalities in the Tobique

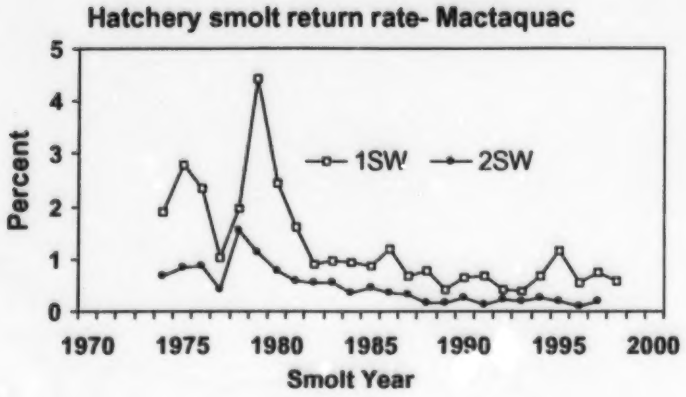
and Beechwood fishways, and 154 1SW and 76 MSW estimated to have been harvested by Maliseet First Nation and does not take into account any of the preceding concerns regarding fallback. Thus, escapements numbered 1,338 MSW and 2,962 1SW salmon. About 95% of MSW escapees were female, more than 90% of 1SW escapees were male. Fish held for broodstock were predominantly June/July arrivals, which yielded 1.9 million eggs, about 15% of the eggs arriving at Mactaquac.

Conservation requirements above Mactaquac are based on an accessible salmon-producing substrate of 13,472,200 m^2, an assumed requirement of 2.4 eggs per m^2, a length-fecundity relationship for Saint John River salmon (Marshall *et al.* MS 1998) and biological characteristics for wild 1SW and MSW salmon, 1988-1995. Requirements are 32.33 million eggs to be provided by 4,900 MSW and 4,900 1SW fish. The biological characteristics and preliminary estimates of numbers of salmon escaping in 1999 indicate that 31% of the conservation egg requirement (59% of the total derived from hatchery-origin fish; 11% from hatchery and wild 1SW fish) was met. This is the sixth lowest value in 30 years.

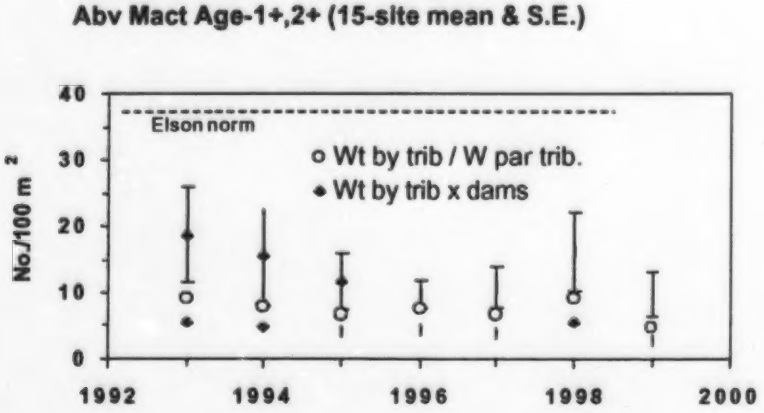
Saint John River, upstream of Mactaquac



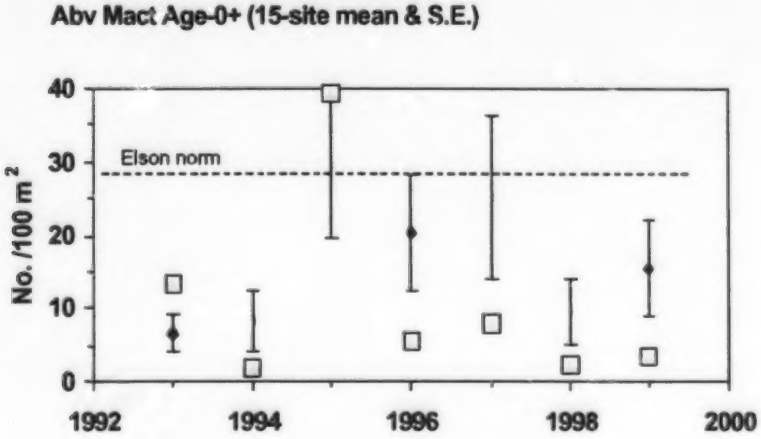
Aged returns of hatchery 1SW and 2SW fish released from Mactaquac Hatchery via the migration channel as one-year smolts have been used as an index of marine survival. Analyses indicate a 1SW return rate of 0.56% from smolts released in 1998, down from the 0.74% value in 1998 and the 0.7% mean value since the complete conversion to a one-year smolt program in 1985. Hatchery MSW returns more than doubled to 0.20% from the 0.082% value in 1998 and approximates the 0.19 mean value since 1988.



Densities of juvenile salmon are currently estimated for about 40 sites electrofished by Aboriginal communities upriver of Mactaquac. Sites on the Tobique (three), Becaguimec (four), Shikatehawk (four), and Meduxnekeag (four) rivers have a continuous record since 1993. The average densities of age-1^+ and older parr for the 15 sites in 1999 was 9.8 (standard error of 3.3) per 100 m^2, the lowest of the series (see Figure below). Weighting of the densities according to the relative production areas of the four tributaries upstream of Mactaquac yields an overall density of 4.8 parr per 100 m^2. Weighting by survival in ultimately descending three dams (Tobique smolts @ 0.486) versus one dam (Shikatehawk, Becaguimec and Meduknekeag @ 0.763; results from coded wire tag experiments in 1990-1992) suggests an effective parr density of 2.9 parr per 100 m^2.



Average age-0^+ densities at the 15 sites tend to be much more variable, in large part due to the clumping or lack thereof and possibly hatchery stocking. Weighting of the densities according to the relative production areas of the four tributaries upstream of Mactaquac still yields annual variability, particularly in 1995, that is inconsistent with variability of estimated egg depositions.



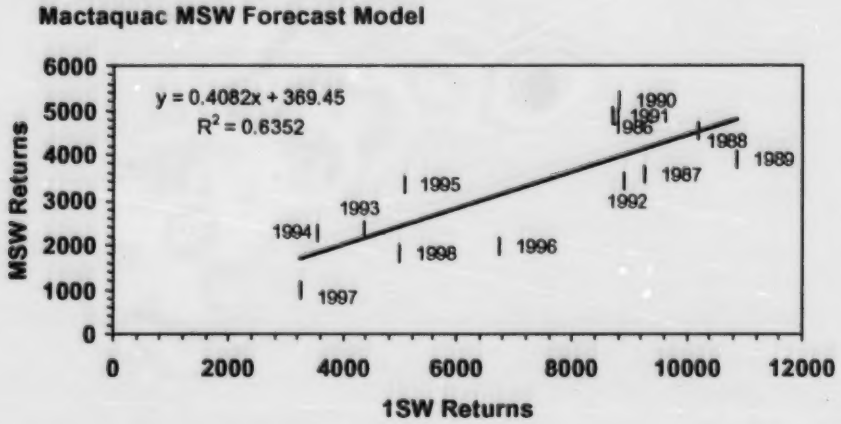
There are no trends in the fry or parr data sets even though the contributing egg depositions trend downwards from 1991 to 1998 (Table 2). Where identified, hatchery-stocked juveniles (300,000 to 900,000 fry and 300,000 to 500,000 fall fingerlings per year) have been excluded. Recent clipping of adipose fins on stocked juveniles reveals that only 5% (Tobique) to 38% (Meduxnekeag) of all age-1^+ and older parr electroseined are of hatchery origin, an observation that is inconsistent with the high proportion of adult returns at Mactaquac that are, without the benefits of adipose clipping, now being classified as being of "hatchery" juvenile origin.

Outlook

Recently, prognoses of returns to Mactaquac has been simplified to Bayes-derived probability of attaining the conservation requirement from the mean and standard deviation of 1SW and MSW returns in the previous five years. These methods were again employed. Additionally, for MSW salmon, forecasts are provided on the basis of the mean 1SW:MSW ratio of the last five years and a regression of MSW returns on 1SW returns (hatchery and wild combined) from the 1985-1997 smolt classes. Hatchery and wild returns were combined so as to reduce the uncertainty of classification in separate treatment of hatchery and wild components. The 1985 starting point was selected so as to include only one-year smolt program among Mactaquac smolt releases and exclude years in which there were homewater commercial and recreational MSW salmon removals included in the estimated returns. In a subsequent testing of years for inclusion or exclusion, the first set chosen provided the most significant regression.

The prognoses for 1SW returns in 2000 is 4,660 (90% CL 2,295-7,020) fish of hatchery and wild origin (presumes that a 10% increase in smolts stocked in 1998 i.e., 300,000 to the 327,384 stocked in 1999 will not significantly increase overall returns). The Bayes derived probability of attaining conservation requirements of 4,900 1SW fish is 43% .

The prognoses for MSW returns in 2000, based on the mean return of the last five years, is 2,060 (90% CL 720-3,430) fish. The Bayes derived probability of attaining a conservation requirement of 4,900 MSW fish (ignores the requirement for 300 MSW broodstock) is zero percent. Conversion of total returns to eggs (using eggs per fish for spawners in 1999) indicates a probability of <1% that 1SW and MSW returns in 2000 will meet conservation egg requirements. The forecast based on the product of the reciprocal of five-year mean ratio (2.5276) and 3,257 1SW fish returning in 1999 is 1,270 (90% CL 807-3,182) MSW returns in 2000 with a Bayes probability (of attaining a ratio value of 0.6646 in the formula 3257/x = 4,900) of near zero. The forecast based on the regression (below) is 1,600 (90% CL 0–3,520) MSW fish.



Recent densities of "wild" juveniles (Table 2) and a consistent supplementation with juveniles surplus to the one-year smolt program at Mactaquac suggest that foreseeable returns will not increase.

Fisheries Management Considerations

For the Saint John River stock upriver of Mactaquac, egg depositions have been trending downwards, reaching a low of 18% of conservation requirement in 1998. Egg depositions in 1999 improved but are estimated to only have met 31% of the conservation requirement. There is essentially a zero probability that returns of MSW salmon or total eggs in 2000 will be sufficient to meet the conservation requirement. There is a 43% chance of attaining the 4,900 1SW salmon requirement from combined hatchery and wild origins.

Generally, 80-90% of MSW salmon returns to Mactaquac are female (95% in 1999). Although males comprise a high proportion of the 1SW salmon (90% in 1999), the egg contribution from the small salmon can be important when large salmon returns are as

low as they are currently. In 1999, the 1SW salmon contributed about 11% of the egg deposition upriver of Mactaquac.

Wild salmon returns were the second lowest (1998 was the lowest) since the construction of Mactaquac Dam in 1968. Only 15% of the 3,257 1SW salmon and 46% of the 1,804 MSW salmon returning in 1999 were identified as wild. While total returns are diminishing and sea survival is low, the decreased return of wild salmon relative to hatchery-origin fish warrants further investigation.

Considering the projected low returns of salmon to Mactaquac Dam, and in particular the low production of wild salmon, fishing mortality should be eliminated. An in-season assessment of stock status will be conducted in mid-July 2000.

Nashwaak River

Fishery

The recreational fishery on the Nashwaak River was also closed in 1999 (Table 1). There was no fishery by Aboriginal peoples in 1999 and there has never been a food fishery allocation specifically for the Nashwaak River. However, it is estimated that a fishery by Aboriginal peoples in the main Saint John downstream of the Nashwaak confluence (Oromocto First Nation and members of the New Brunswick Aboriginal Peoples Council) would intercept fish of Nashwaak River origin. The closures affecting the Nashwaak were consistent with recent failures of the river to approach conservation requirements and prognoses of a near-zero probability for achieving conservation in 1999 (Marshall *et al.* MS 1999a).

Status

Habitat

Numerous forestry operations in the upper part of the watershed may contribute to increased stream temperatures and increasingly variable water discharge patterns. Coincidentally, chain pickerel and smallmouth bass have now been observed in salmon holding pools as far as 50 km upstream of the confluence with the mainstem Saint John River. The return by an angler of a Carlin tag from the stomach of a chain pickerel in the same season that it had been applied to a hatchery-released smolt is consistent with observations in Mactaquac Headpond where pickerel may be effective predators on migrating smolts and possibly overwintering presmolts.

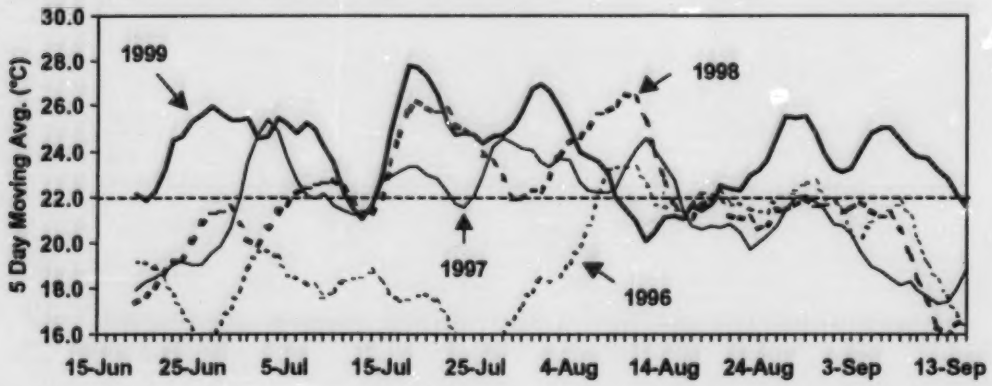
Aeromonas salmonicida, the causative agent of furunculosis, is ubiquitous to the Saint John drainage and can inflict mortality among physically or environmentally stressed fish. Seven dead adults were recovered from the upstream side of the Nashwaak River fence during warm water periods in 1999. Five were submitted to the federal fisheries health lab for disease analyses and all five tested negative for furunculosis and other "identifiable" diseases. In 1997 and 1998 approximately one-half of the adults submitted

tested positive for furunculosis. The 1999 samples were also found to be negative for ISA (infectious salmon anemia) virus.

A commercial salmon hatchery producing smolts for the Fundy-Isles aquaculture industry has been in operation for most of the 1990s on the Tay River tributary. As in 1998, a portable smolt fence operated in May-June, 1999, revealed 385 escapees among 1793 wild smolts. All obvious escapees were either dead (359) inside the fence trap or lethally sampled (26). The likely stock origin of escapees is Saint John River (Mactaquac), but the most immediate lineage is several generations of cage-grown adults. Stocking of the Nashwaak with progeny of "wild" fish returning to Mactaquac ceased in 1995 and minimal stocking since that time has been progeny of adult returns to the Nashwaak River. No viral or bacterial fish pathogens were identified from a sample of 35 suspected aquaculture escapee smolts tested in 1999. Tissue samples were also collected from a proportion of the suspected escapees for genetic "typing".

Water temperatures at the Nashwaak Fence were "warm" for more days in 1998 than any of the previous four years. Days in which temperatures equaled or exceeded 22°C numbered 79 in 1999 compared to 40 days in 1998, 36 days in 1997, and 22 days in 1996. As noted at Mactaquac, warm temperatures began earlier in the season than in previous years.

Maximum Water Temperature - Nashwaak River



Stock

Returns of salmon to the Nashwaak River between June 3 and October 14, 1999, were largely derived using mark-and-recapture methods and Bayes estimation procedures. Marks were applied to all fish ascending the Nashwaak River fence except for those migrating during two separate three-day high water events in September. Counts of marked and unmarked fish were obtained by seining pools above the fence on October 13 and 14. The few fish that were captured at the fence until high water topped the fence again on the evening of October 14 were added to the mark-and-recapture estimate. Shortage of manpower did not allow for fence operation to continue once the water level

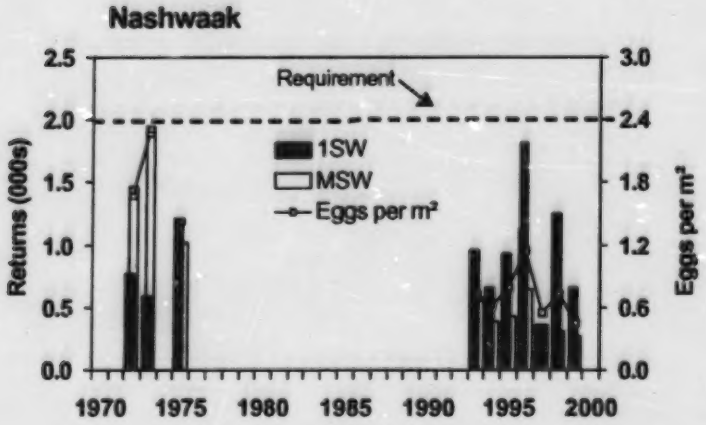
dropped and so the fence was removed on October 19. Adequate fall discharge and the low percentage (less than 2%) of wild returns to Mactaquac after October 14 would suggest that few adults would have ascended the Nashwaak thereafter. The 1999 fall discharge patterns were also similar to those observed in 1998 when few fish were passed above the fence, October 14-27.

Counts of small and large salmon (adjusted for interpretation of sea-age on scales) at the Nashwaak fence, suggested passage of 305 1SW and 84 MSW salmon. Seining and capture of 12 marked and 21 unmarked fish above the fence in October resulted in separate mark-recapture estimates of 665 1SW and 275 MSW salmon (Table 2). Based on external characteristics, hatchery returns from minimal distributions of juveniles to the river contributed to less than 1% of the total returns. No farmed fish were identified on the basis of gross external fin deformation noted among Tay River escaped smolts.

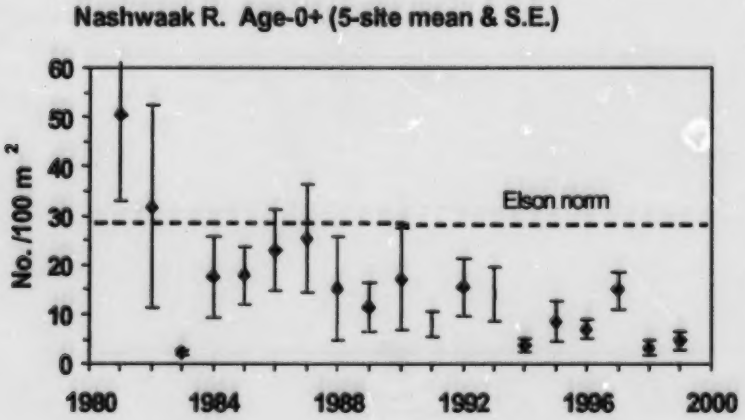
Returns to the Nashwaak in 1999 were affected by the low June-to-August river discharge levels. Also, two salmon and one grilse (of Nashwaak origin) tagged at Mactaquac and released at Woodstock were recaptured at the fence or during seining operations. Adjustment for low fence efficiency and other untagged wild salmon released at Woodstock suggest that as many as seven salmon and seven grilse of Nashwaak origin were released at Woodstock and returned to the Nashwaak. No information is available to assess the number of Nashwaak adults that may have been transported and remained above Mactaquac or that may have been lost to turbine mortality as they returned downstream.

Estimates indicate that the 1SW returns were the third lowest since resumption of the fence operations in 1993, and half the total 1SW return of 1998. MSW returns were the lowest on record and have been steadily declining since 1996.

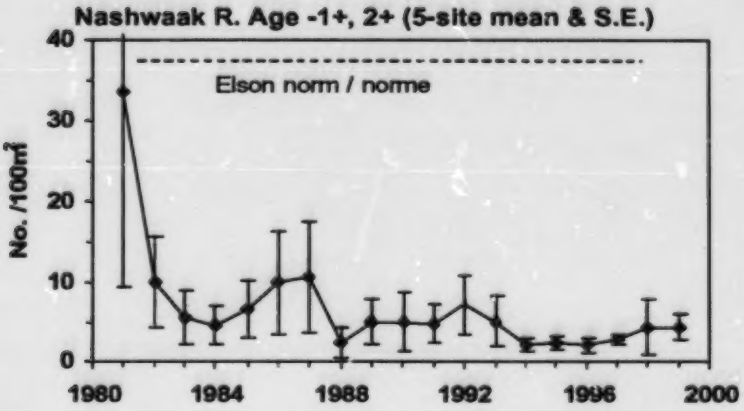
Conservation egg requirements for an estimated 5.35 million m^2 of substrate (> 0.12% gradient) above the fence are 12.8 million eggs. This egg requirement is on average obtainable from 2,040 MSW salmon, an equal number of 1SW salmon are needed to provide males. Estimated returns minus known removals (mortalities and broodstock to supply juveniles for two satellite rearing units operated by Nashwaak Watershed Association) suggest an escapement of 660 1SW and 270 MSW salmon. A length-fecundity relationship for Saint John origin salmon (Marshall *et al.* MS1998) and biological characteristics of fish captured at the fence indicates egg deposition in 1999 to have been only 19% of requirement, lowest since the fence operations resumed in 1993. As in previous years, females among 1SW salmon (46%) contributed to a large proportion, 43%, of the total estimated egg deposition.



Juvenile densities have been monitored since 1981 at two tributary and five mainstem sites located above the Nashwaak River counting fence. Densities at one tributary and four mainstem sites during the 1980s have been adjusted (remainder to be completed in 2000) to reflect the expanded site areas initiated in 1990-1991. The 1999 density for age-0^+ parr continues to be low; the data continue to trend downwards ($p< 0.001$). No values in the last decade have approached an Elson (1967) normal abundance of 28 parr per 100 m^2 (Table 2).



The five-site age-1^+ and older parr density in 1999 was unchanged from that of 1998. The data trend downwards ($p= 0.01$) since 1981. The low densities of the 1990s, <20% of an Elson (1967) norm of 38 fish, and failure of resultant adult returns to meet more than 25-50% of conservation egg requirements suggest that requirements will not be approached in the foreseeable future.



Between late-April and early June, 1999, a partnering with Nashwaak Watershed Association allowed for a mark-and-recapture estimate of smolt output from the area above the adult fence. As in 1998, this was accomplished by capturing and marking (100% adipose clipped and 50% with streamer tags) smolts at a portable counting fence on the Tay River tributary and sampling (marked:unmarked ratio) at a smolt "wheel" (financed by NB Wildlife Trust Fund and entrusted to the Atlantic Salmon Federation) moored in the main Nashwaak just above the adult fence site. The Tay River fence was installed and operational on April 28 and catches peaked during the period of May 3-8 when 1,200 smolt were marked and released. Unlike 1998, the suspected aquaculture escapee catches were simultaneous with the wild run (Marshall *et al.* MS 1999b).

The smolt wheel or rotary fish trap was operational on April 20 and 300 smolts were captured before the end of April. Wild smolt catches at the wheel peaked during the period May 6-8 when 1,000 smolts were captured. Few smolts (less than 10/day) were captured after May 15. Recovery at the wheel of 138 smolts marked in the Tay River and an additional 2,100 unmarked smolts (excluding four aquaculture escapees) contributed to a mark-and-recapture estimate of about 28,500 (90% CL 25,300-33,200) migrating smolts (0.5 smolts per 100 m^2 of production area). The estimate is a 25% increase over that of 1998 and is consistent, at least for the dominant two-year smolts, with the estimated increases in egg depositions, 1995 to 1996, age 0^+ parr, 1996 to 1997 and age 1^+ and older parr, 1997 to 1998.

Outlook

Two prognoses of 1SW returns in 2000 are possible. The first is the 1,015 1SW (90% CL 235-1,945] mean of returns in the previous five years. Bayes derived probabilities for the same data indicate that there is only a 3.5% probability that 1SW requirements of 2,040 1SW fish will be met. A second prognoses of 830 wild salmon is based on the product of the 2.91% return rate (five times the 1SW return rate from Mactaquac Hatchery smolts) of the 1998 smolt class as 1SW fish (Marshall *et al.* MS 1999b) and the estimated 30,000 wild smolt descending in 1999.

Two prognoses for MSW salmon returning in 2000 are also possible. The five-year mean of MSW returns to the fence is 410 fish (90% CL 165-655) and a zero probability of meeting the 2,040 MSW salmon conservation requirements. The product of the five-year mean ratio 2SW/1SW returns for the smolt years, 1993-1997, and 1999 1SW returns suggests that 2SW returns will number 190 fish [minimum – maximum of 100-260].

Fisheries Management Considerations

The Nashwaak River stock failed in 1999 to achieve its conservation requirement. Only 19% of the requirement was met and expectation is a near-zero probability for achieving conservation in 2000. The stock of this river is also assumed to be representative of stocks of the Saint John River downriver of Mactaquac.

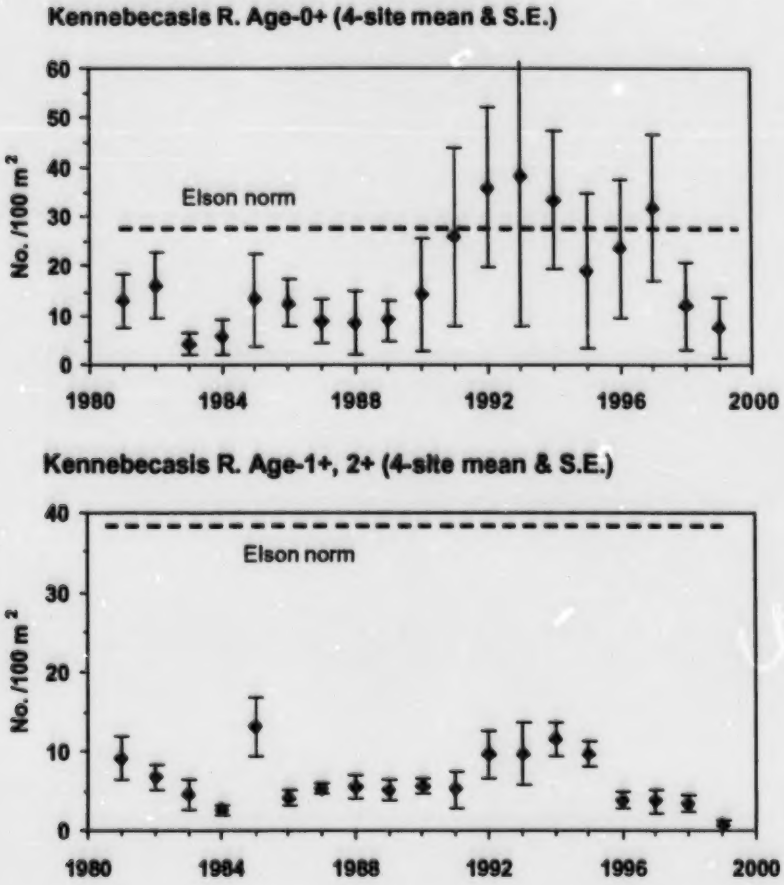
Considering the high female component (30-50%) in the stocks downriver of Mactaquac, losses of small salmon to exploitation would directly and significantly affect egg depositions and achievement of conservation requirements, particularly now when large salmon returns are inadequate to meet requirements. As well, on the Nashwaak River, juvenile salmon of non-Nashwaak River origin fish should be prevented from escaping the Tay River hatchery.

Kennebecasis River

As mentioned previously, the 1998 and 1999 fisheries for salmon on the entire Saint John River and tributaries were closed to both Aboriginal and recreational fishers. Closures of tributaries downstream of Mactaquac were based on the assumption that the near-zero probabilities of attaining conservation requirements upriver of Mactaquac and on the Nashwaak River were true elsewhere within the system.

Unlike 1996 and 1997, (Marshall *et al.* MS 1998) there is no assessment in 1999 of salmon ascending the low-barrier fence. Salmon ascending the fence numbered 18 1SW and 1 MSW fish but the late-season high water reduced upstream sampling and precluded sampling of downstream migrating post-spawners for counts of marked and unmarked fish and the attainment of a mark-and-recapture population estimate. Incomplete counts under somewhat lower flow conditions in 1996 and 1997, when it was estimated that less than 50% of conservation requirements (above the fence) were achieved, were 82 1SW and 47 MSW fish, and 74 1SW and 44 MSW fish, respectively.

Densities of both age-0^+ and age-1^+ and older parr at four sites on the system in which data for the years 1981-1989 have been standardized to the expanded index sites instituted with mark-and-recapture techniques in 1990, were the lowest of the 1990s, and in the case of age-1^+ and older, lowest of the period of record. Current data and downward trend are suggestive of decreasing adult recruitment in the foreseeable future.



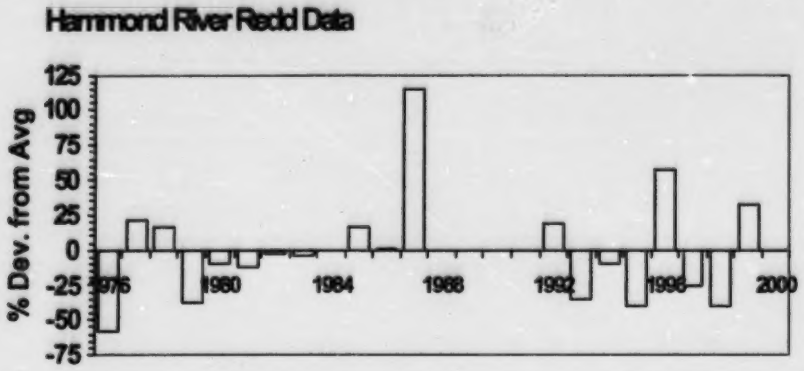
Hammond River

As mentioned above, the 1998 and 1999 fishery for salmon on the entire Saint John River and tributaries was closed to both Aboriginal and recreational fishers. Closures of tributaries downstream of Mactaquac were based on the assumption that the near-zero probabilities of attaining conservation requirements upriver of Mactaquac and on the Nashwaak River were true elsewhere within the system.

Unlike 1998, there was no assessment of adult returns to the Hammond River in 1999. A redd count (Pettigrew[1], pers. comm.) of 199 large (280 small and large) redds, under moderate flows with good visibility on the 11.75 km of spawning habitat on the upper mainstem, was 216% of that of 1998 and 134% of the previous five-year mean. Total redd

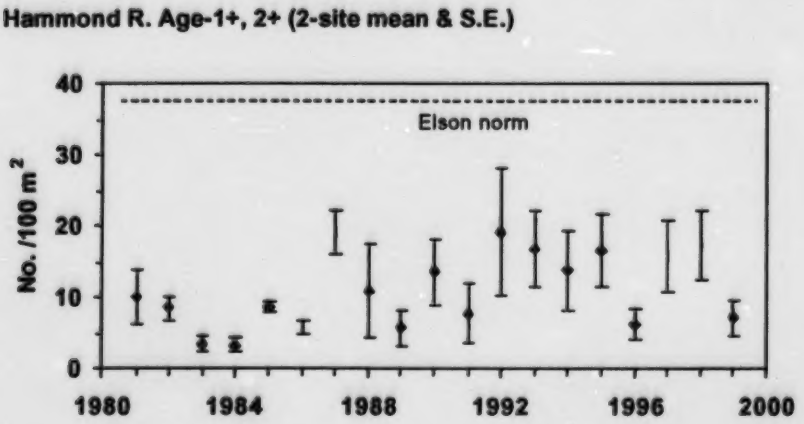
[1] T. Pettigrew, NBDNRE, PO Box 150, Hampton, NB E0G 1Z0

counts adjusted to the average for each of high, moderate and low flow conditions (Pettigrew[1], pers. comm.; there were no counts in 1984 and 1988-1991) are:



A count of 111 large redds in 1998 was estimated to have approximated the conservation requirement for the 11.75 km survey area. However total returns to the river as estimated by mark-and-recapture techniques were only about 30% of a 530 MSW and 680 1SW conservation requirement (Marshall *et al.* MS 1999b).

Densities of juvenile salmon (age-1^+ and 2^+ parr) at four sites on the Hammond River in 1999 averaged 7.2 parr per 100 m^2, less than one-half of many values in the 1990s. The low density is evident in a two-site average, 1981-1999, in which data for the years 1981-1989 have been standardized to the expanded index sites instituted with mark-and-recapture techniques in 1990. An adjusted four-site average should be available in 2000.



Four site densities will be about 25% less than those recent values depicted above but will in general be three to four times those values of the four- and five- site average values shown

earlier for the Kennebecasis and Nashwaak rivers. The influence of hatchery stocking on these densities is believed to be minimal.

Age-0^+ parr averaged 19.2 fish per 100 m^2 (four sites), the second lowest of the 1990s. Densities of age-0^+ and age-1^+ and older parr are, and have generally been, less than normal parr abundance (Elson 1967; 29 age-0^+ and 38 age-1^+ and older parr [broken line in above Figure]). The near-absence of estimates of adult escapement makes both juvenile and redd count data almost impossible to interpret. A relationship between flow-standardized redd counts and four-site standardized juvenile densities will be examined in 2000.

Magaguadavic River

Fishery

In 1999 the fishery for salmon on the Magaguadavic River, as with all rivers tributary to the outer Bay of Fundy, was closed. There has been no allocation of salmon from the Magaguadavic River to Aboriginal peoples.

Status

Habitat

A 13.4 m-high dam and 3.7 megawatt hydroelectric station is located at the head-of-tide and is a complete obstruction to migrating fish. Upstream passage is by means of a pool-and-weir fishway; assessment of the anadromous resource(s) is afforded by a trap in the third pool from the top of the fishway. Downstream passage is through a sluiceway adjacent to the penstock. There are more than 55 lakes within the drainage, three of which have controlled outlets and serve as reservoirs for power production (Whoriskey *et al.* MS 1998). Smallmouth bass were introduced to the drainage in the 1930s or 1940s and with landlocked salmon (*Salmo salar*) provide popular recreational fisheries.

The Magaguadavic River is the most proximate large river to the centre of the "Fundy-Isle" salmon aquaculture industry (approximate current production of 20,000 t) and as such has attracted more salmon escapees than any other monitored river in eastern North America. Three commercial salmon hatcheries, which produce more than two million smolts of cage parentage (originally Saint John River) for the industry are located within the drainage and escapees have been noted among riverine samples of juvenile salmon (Whoriskey *et al.* MS1998). River discharges were low and temperatures high through much of the June-August period.

Stock

In 1999, as in recent years, the Atlantic Salmon Federation, with funding from NB Wildlife Trust, monitored the trap in the St. George fishway, late-June through November, and provided summary data and analyses (Carr[2], pers. comm). In 1999, as in the past three years, no fish of aquaculture origin captured at the trap were released to the river. Rather,

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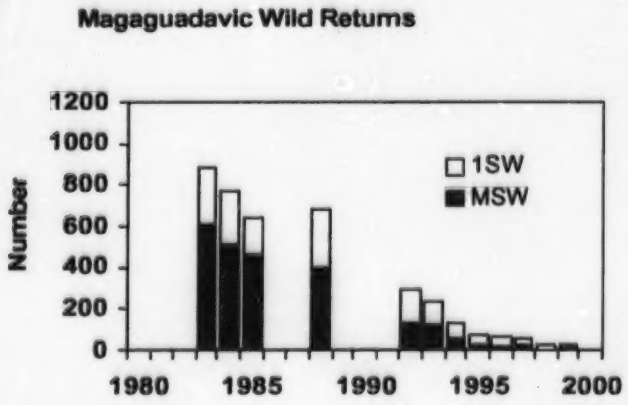
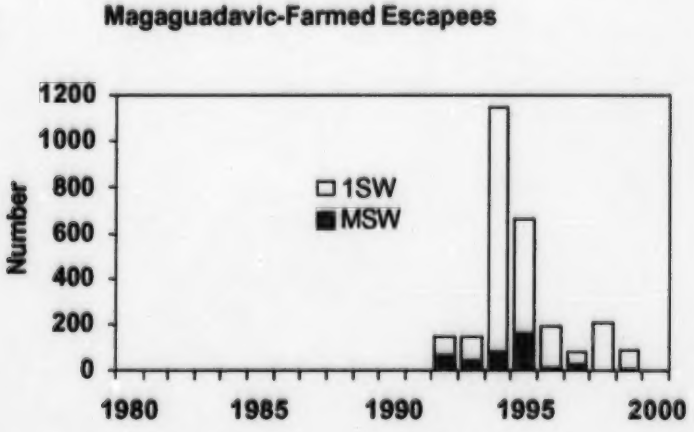
[2] J. Carr, Atlantic Salmon Federation, PO Box 429, St. Andrews, NB E0G 2X0.

they were released to various points in the Bay (as part of a homing experiment) or sacrificed for sampling of pathogens. Release of fish of aquaculture origin to other points in the Bay was curtailed in 1999 when a fish tested positive for ISA. Intentional stocking of "hatchery" fish (those fish reared and released with the intent of stock enhancement) have, with exception of a small satellite rearing project (releases are marked by removing the adipose fin), been absent on the Magaguadavic River over the recent record.

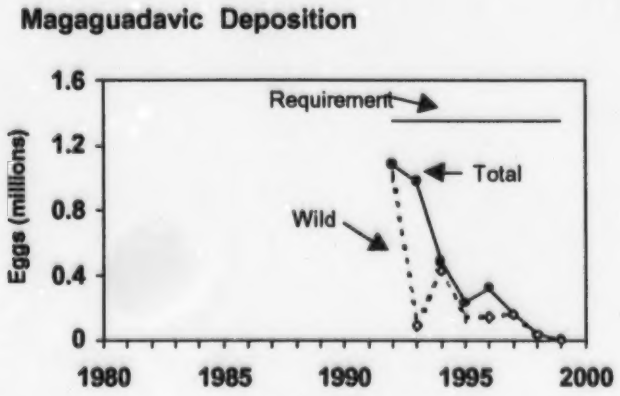
Wild returns in 1999 numbered only 19 1SW and 5 MSW salmon, the fewest of record.



Five of the returns were found dead in the fishway. Farm-origin fish ascending the fishway in 1999 numbered 80 1SW, 10 MSW and represent the second lowest count since 1992.



Interim conservation requirements are 1.35 million eggs (Marshall *et al.* MS1998). Spawners necessary to obtain those eggs are estimated at 230 MSW and 140 1SW salmon, an objective which in all likelihood was met in the 1980s (see wild returns graph). Only four 1SW fish were released to the river in 1999, one of which was a female with a potential 3,250 eggs (Carr[2], pers comm.) the lowest of record. Eleven broodstock (three MSW and five 1SW females with three males) yielded about another 30,000 eggs which are being held under quarantine at the NB Research and Productivity Council pending testing for the ISA virus in the spring of 2000.



Densities of juvenile salmon are available for five sites in 1995 and four sites in 1997 (Carr and Whoriskey MS1997). The only repeated site indicated an increase in fry and parr densities but this site is proximate to a commercial hatchery. Fry densities were low (0-8.6 per 100 m^2), parr densities ranged from 0.1-55.0 per 100 m^2 and juvenile smallmouth bass were present (up to 12.0 fish per 100 m^2; mostly age-0^+) in all sites (Carr and Whoriskey *op. cit.*). Nine electrofishing sites were completed in 1999, two sites proximate to the hatcheries contained up to 14 "parr" per 100 m^2, the sites distant to the hatcheries had 0-0.4 fish per 100 m^2 (Carr[2], pers. comm.).

Outlook

Prospects for wild MSW returns in 2000 (and beyond) are poor. Wild 1SW fish have diminished annually and the equation MSW= 0.8984(1SW)- 26.63 ($n=7$; $R^2_{adj}=0.94$; $p<0.001$) from count data 1992-1998 suggests that wild MSW returns in 2000 will be zero. 1SW recruitment has been weak and estimated egg depositions 1995-1996 (above) supports the contention that recruitment in 2000 (and beyond) is unlikely to exceed a dozen returns. Mean estimated egg deposition, 1995-1998, was 0.24 million or 21% of conservation requirements. Assuming that these depositions are indicative of those of the next few years, there is a zero probability (Bayes probabilities from the mean and standard deviation) of egg depositions being equal to or greater than the 1.35 million egg requirement.

Fisheries Management Considerations

Returns of wild salmon to the Magaguadavic River in 1999 numbered only five large and 19 small salmon. There is no chance that conservation requirements will be met from natural production in this river for the foreseeable future.

The wild stock should be preserved by the continued removal of aquaculture fish from the escapement, by ensuring containment of non-native juveniles within industry hatcheries in the drainage, and by maintenance of the existing Magaguadavic gene pool in an artificial rearing station.

St. Croix River

Fishery

In 1999 the fishery for salmon on the St. Croix River, as with all rivers tributary to the outer Bay of Fundy, was closed. There has not been an allocation of salmon from the St. Croix to Aboriginal peoples.

Status

Habitat

The St. Croix River is a USA/Canada international river bordering the State of Maine and Province of New Brunswick which drains southeasterly into Passamaquoddy Bay of the Bay of Fundy. Approximately 1,619 km^2 of the drainage basin is in New Brunswick and 2,616 km^2 is in Maine. Once a significant producer of Atlantic salmon, the river and stocks succumbed to industrial development - initially cotton mills and tanneries, then pulp mills, and now hydroelectric dams and headponds at Milltown, Woodland (including paper mill), Grand Falls, and water control structures at Canoose in New Brunswick and East Grand Lake and other sites in Maine, and at St. Croix and Forest City on the mainstem boundary waters.

All dams have upstream fish passage facilities which allow access to the major salmon producing area of the East Branch (Grand Falls to St. Croix) and Monument Brook boundary waters. Downstream passage facilities have been improvised but their effectiveness is largely unknown. Water quality is monitored by the International Joint Commission and has improved such that juvenile salmon have on occasion been found in the mainstem downstream of Woodland. In 1999, May and June river temperatures were 3-4°C above seasonal norms and, river discharges dropped to minimum levels (200 cfs on the upper river and 750 cfs on the lower portion) for the first time in many years (Sochasky[3] pers. comm.). As a result unfavorable fish passage conditions existed on the St. Croix from June into September.

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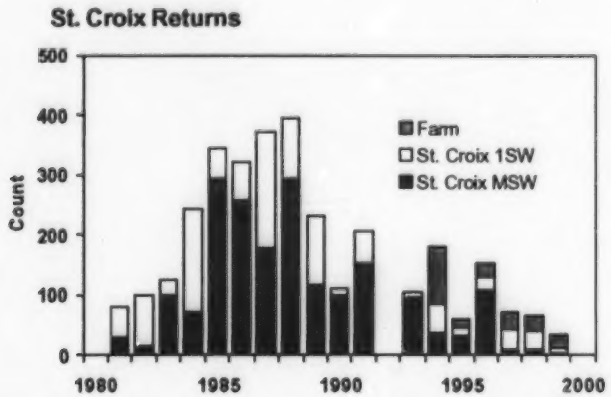
[3]L. Sochasky, St. Croix International Waterway Commission, #5 Route 1, Dufferin, St Stephen, NB E3L 2Y8.

The St. Croix River is also proximate to the Canadian Fundy-Isles and US Cobscook Bay region salmon aquaculture industries (total production of about 32,000 t) and as such has attracted farm escapees, but in fewer numbers than the Magaguadavic River. Within the drainage there are State of Maine hatcheries rearing landlocked salmon but none rearing fish for the aquaculture industry. The river and lakes are home to significant populations of smallmouth bass and important associated fisheries.

Stock

The original St. Croix stock was extirpated and present-day wild and hatchery returning salmon are the result of rehabilitation efforts using fish of Penobscot and Saint John origins (Anon MS 1988). Conservation requirements for the habitat suitable for salmon production is currently 1,710 MSW and 680 1SW fish. Based on present stocking schedules, returns and escapements, salmon will not approach conservation requirements in the foreseeable future.

Counts of salmon at the Milltown fishway, just above head-of-tide, between May 4 and November 12, 1999 numbered 36 fish comprised of five wild and hatchery MSWs and 8 wild and hatchery 1SWs (Sochasky[3] pers. comm.), the lowest of recent record. External characteristics indicated that there were also 11 MSW and 12 1SW fish of aquaculture origins which were removed from the trap and submitted to disease analysis by the US Fish and Wildlife Service and tested negative for ISA virus. Intentionally stocked fish numbered 3 MSW and 1 1SW salmon.



All 13 hatchery/wild fish were taken as broodstock and yielded 23,600 eggs for hatchery incubation. Thus no salmon escaped to spawn naturally above the Milltown Dam.

Outlook

Mean numbers of wild and hatchery MSW and 1SW returns, 1995-1999, have been 33 and 22 fish, respectively. Recent levels of natural spawning indicate that returns of each of 1SW and MSW fish in 2000 or the near future will number more than one or two dozen fish.

Returns from 52,000 and 124,400 age-0^+ parr released in 1996 and 1997, and 21,300 Penobscot smolts released in 1999 offer hope some hope for a few additional 1SW returns The MSW component from the 1997 and 1999 releases would not be expected until 2001 and, utilizing a Mactaquac return rate of 0.2% on each of the two lots might yield upwards of 300 fish.

Fisheries Management Considerations

Unlike the Magaguadavic River, the St. Croix has probably never attained conservation requirements in the 20th century. The probability of attaining those requirements is zero and to achieve such a goal will require significantly more support than is currently available. The downward trend in returns since 1984 may in part reflect changing enhancement initiatives but is also consistent with the downward trend in wild stocks in southwest New Brunswick. To preserve the current "stock" there can be no fishing mortality on returns and fish of aquaculture origin must be removed. Continued hatchery intervention is required to prevent certain extirpation of this developing salmon stock.

SUMMARY

Stocks in southwest New Brunswick have generally not been meeting conservation requirements during the last decade and have been closed to recreational retention fisheries for 1SW salmon since September 15, 1993. There were virtually no salmon fisheries in 1995 and none in 1998 and 1999. In-season assessments at Mactaquac have been used as and largely observed to be an index of stock status throughout southwest New Brunswick.

In the Saint John River upriver of Mactaquac, generally 80-90% of MSW salmon (95% in 1999) are female while in the 1SW fish a high proportion are male (90% in 1999). Since 1985, egg depositions have been trending downwards and there is essentially a zero probability that total returns in 1999 will meet egg conservation requirements. There is a 43% chance of attaining the 4,900 1SW salmon requirement. Stable but "low" densities of "wild" juveniles and a consistent supplementation with juveniles surplus to the one-year smolt program at Mactaquac are not suggestive of increases in future returns unless there is an increase in survival in the smolt, post-smolt or maturing adult stages. Hence, fishing mortality, particularly in the Tobique River, should be minimized prior to in-season assessments in July of 2000.

In tributaries of the Saint John downriver of Mactaquac, there is an important female component in the 1SW salmon size group. In the Nashwaak River, 1SW salmon contributed 43% of the estimated egg deposition as a result of the low MSW salmon abundance and the high percentage females (46%) among small salmon. In the Hammond and Kennebecasis rivers, the proportion female in the 1SW salmon component has been greater than 25% in the recent years' sampling. For the Nashwaak, River, there is a near-zero probability that 1SW or MSW returns will meet conservation requirements in 2000. Recent consistency between low stock levels at Mactaquac and the Nashwaak suggest

that the in-season assessment at Mactaquac in late-July could also be an index of status for the Nashwaak River.

Other outer Bay of Fundy rivers which have been assessed include the Magaguadavic River in which wild stocks have made dramatic declines in the last decade, and St. Croix River in which salmon have been introduced in modest numbers following extirpation nearly a century ago. Both rivers are proximate to and heavily impacted by the Fundy-Isles (Canada) and Cobscook Bay (USA) salmon aquaculture industries which together have an annual production of about 30,000 t. Prospects for wild MSW returns to both rivers in 2000 (and beyond) are poor and will not exceed the few dozen fish now returning to each. 1SW recruitment has also been poor and returns in 2000 and beyond are also unlikely to exceed the two to three dozen fish observed in each of 1997, 1998 and 1999. There is a zero probability of meeting the conservation requirements in the Magaguadavic River and at the present level of development, a zero probability of meeting requirements on the St. Croix River (although there be a multifold increase in MSW returns in 2001 from enhancement initiatives). Thus management for zero fishing mortality on wild (both rivers) and hatchery (St. Croix only) returns must continue as must also the continuation of removals of any aquaculture fish from the escapement. On the Magaguadavic River, the potential for introgression can further be reduced by ensuring "containment" of non-Magaguadavic River juveniles within industry hatcheries located in the drainage.

ACKNOWLEDGEMENTS

Compilation and synthesis of these assessments have been made possible only with the support of many co-workers. Counts of salmon essential to the assessment on the Saint John were provided by the staff, particularly D. Sutherland at Mactaquac FCS and field supervisors J. Mallery and C. Fitzherbert. Counts of salmon at Tobique Narrows were assisted by Maliseet First Nation, counts of salmon at Beechwood were provided by NB Power and counts of salmon at Tinker Dam were provided by PDI Canada Inc. The Kingsclear First Nation operated the salmon counting fence on the Nashwaak River. The above mentioned First Nations, Saint Mary's, Woodstock First Nations, the Tobique Salmon Protective Association (particularly R. O'Donnell), and the Hammond River Angling Association were instrumental in conducting electrofishing. D. MacPhail, Silvacare Inc., determined ages for salmon scales sampled at Mactaquac. L. Sochasky and D. McLean, St. Croix Recreational Fisheries Development Program, provided counts and scales from salmon ascending the Milltown fishway. J. Carr, Atlantic Salmon Federation, provided counts and analyses for the Magaguadavic River. Also to Tom Pettigrew and John Blenis from NBDNRE for updates and analyses on the Hammond River redd counts and the Nashwaak Watershed Association (particularly G. Spencer and W. Gammond) for their participation in the Nashwaak smolt project and the Atlantic Salmon Federation and the NB Wildlife Trust Fund for use of the smolt wheel. P. Cronin, NBDNRE, reviewed and K. Rutherford edited the manuscript.

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Table 1. Fisheries removals (number of fish) of Atlantic salmon from rivers of southwest New Brunswick, 1995 to 1999. Removals refers to losses to spawning resulting from fishing activity. For the recreational fisheries, the removals include losses estimated to have occurred as a result of hook-and-release induced mortality.

			Aboriginal Fisheries Removals [1]										Recreational Fisheries Removals [1]									
			Small Salmon					Large Salmon					Small Salmon					Large Salmon				
River	SFA	Index	'95	'96	'97	'98	'99	'95	'96	'97	'98	'99	'95	'96	'97	'98	'99	'95	'96	'97	'98	'99
Saint John at / upr Mactaquac	23	37	50	675	361	Closed	154	25	285	265	Closed	76	Closed	50	24	Closed	Closed	Closed	25	15	Closed	Closed
Nashwaak	23	38	Closed	-	-	Closed	Closed	Closed	-	-	Closed	Closed	Closed	14	5	Closed	Closed	Closed	5	3	Closed	Closed
Magaguadavic	23	39	Closed	0	0	Closed	Closed	Closed	0	0	Closed	Closed	Closed	<1	<1	Closed	Closed	Closed	1	<1	Closed	Closed
St. Croix	23	40	Closed	0	0	Closed	Closed	Closed	0	0	Closed	Closed	Closed	<1	<1	Closed	Closed	Closed	<1	<1	Closed	Closed

[1] "Closed" means no salmon fishing was allowed, "-" means no data were available, "0" means no removals occurred.

Table 2. Summary of stock status of Atlantic salmon in southwest New Brunswick, SFA 23.

River	SFA	Method	Map Index	Returns in 1999		% hatchery origin	Conservation met		Qualitative estimate of abundance			Status in 1999		Potential Constraints to Production
				Small	Large		1999	1984 - 1999	Juveniles	Adults		rel. to 1998	1984 to 1998	
										Wild	Hatchery			
Saint John at / abv. Mactaquac	23	Fw	37	3257	1804	74%	No	2 of 16 ↓	Low ⇔	Low ↓	High ⇑	⇑	↓	Fp, LU, WU
Nashwaak	23	Fe/MR	38	665	275	< 1%	No	0 of 7 ⇔	Low ↓	Low ⇔	Low ⇔	↓	↓	LU, WU
Magaguadavic	23	Fw	39	19	5	0%	No	3 of 11 ↓		Low ↓		↓	↓	Fp, AQ, WU
St. Croix	23	Fw	40	8	5	31%	No	0 of 15 ↓		Low ↓	Low ⇔	↓	↓	Fp, AQ, WU

Assessment methods: Ang = angling catches and assumed exploitation rates; CR = catch rate index; Electro. = Index of abundance, juveniles and adults.
Fe = counting fence; Fw = fishway; MR = mark and recapture experiment
Sh = shore count; Vi = snorkel count; ViM = snorkel count and mark/recapture calibration

Map index numbers refer to text figure and legend.

Trend symbols (over recent ten years): ↓ = decline; ⇔ = no change; ⇑ = increase (Low, Med & High = qualitative)

Potential constraints to production: Ac = acid impacted rivers; Aq = aquaculutre escapees; WU = water use practices
Fp = fish passage constraints; LU = land use practices